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FORM PTO-1390 (Rev. 11-2000) U.S. DEPARTMENT OF COMMERCE ATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 505500-60

U.S.APPLICATION NO. (If known, see 37 CFR 1.5): 09/937113

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP99/05669	October 14, 1999	March 26, 1999

TITLE OF INVENTION: THREE-DIMENSIONAL IMAGE DISPLAY DEVICE

APPLICANT(S) FOR DO/EO/US: Takeyoshi Dohi, Susumu Nakajima, Ichiro Sakuma, Ken Masamune, Hiroshi Iseki, Etsuko Kobayashi, Sumihisa Orita

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to being national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is attached herewith (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☒ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☒ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A **FIRST** preliminary amendment.
14. ☐ A **SECOND or SUBSEQUENT** preliminary amendment.
15. ☒ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 15(d)(4).
20. ☒ Other items or information: Copy of published International Application 113,338; IPER 416; IPER 408; Japanese language annex to IPER; IB 338; IPEA 401; red line version of substitute specification and claims showing changes to priority document, pages 6 and 7 of specification are replaced by amended pages

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/937113	PCT/JP99/05669	505500-60

21. ☒ The following fees are submitted:		CALCULATIONS PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO and JPO	$1000.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	$860.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	$710.00	
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)	$690.00	
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)	$100.00	

ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 1,000.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total Claims	12 - 20 =	0	X $18.00	$ 0	
Independent Claims	2 - 3 =	0	X **$80.00**	$ 0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$270.00**	$ 270.00	
TOTAL OF ABOVE CALCULATIONS			=	$ 1,270.00	
☒ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2				$ 635.00	
SUBTOTAL			=	$ 635.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f))				$	
TOTAL NATIONAL FEE			=	$ 635.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property				$	
TOTAL FEES ENCLOSED =				$ 635.00	
				Amount to be refunded:	$
				charged:	$

a. ☒ A check no. **5677** in the amount of **$635.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. **03-0678** in the amount of $____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **03-0678**. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit Card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

William Squire
Carella, Byrne, Bain, Gilfillan, Cecchi, Stewart & Olstein
6 Becker Farm
Roseland, New Jersey 07068
Tel: (973) 994-1700
Fax: (973) 994-1744

9/20/01

SIGNATURE

NAME
William Squire

REGISTRATION NUMBER 25,378

AMENDMENT IN SPECIFICATION

[Received by the Japanese Patent Office on 23 October, 2000 together with the Demand for international preliminary examination]

Page 3, line 2, replace "other" with a lot of.

Page 4, line 8, replace "a new light source O" with a new apparent light spot O.

Page 5, line 10, insert not only on the surface but also including inside of the object after "the number of points".

Page 5 line 29 to page 6 line 4, replace "an operating means to calculate the furthest point from the image display means among points intersecting the object image to be displayed , on a line starting from each pixel on the image display means, passing through the center of the curvature of the convex surface of a plurality of the respective convex lenses" with an operating means to calculate only the furthest point from the image display means among points intersecting the object image to be displayed determined by the operating means, on a light starting from a pixel on the image display means, passing through only the center of the curvature of the convex surface of a plurality of the respective convex lenses among lights heading for a plurality of the convex lenses.

Page 6 lines 12-15, replace "the operating means to calculate the furthest point from the image display means among points intersecting the object image to be displayed, on a line starting from the pixel on the image display means, passing through a plurality of respective pin holes" with the operating means to calculate only the furthest point from the image display means among points intersecting the object image to be displayed determined by the operating means, on a light starting from the pixel on the image display means, passing through a plurality of

respective pin holes among lights heading for the light shielding plate.

Page 6 line 21, insert including pixels not only on the surface but also after "a resolution".

Page 7 line 20, insert between the image displayed in the three-dimensional space and the observer after "By introducing the diffusing plate".

Page 11 line 23, delete "When the above-mentioned operation is executed," and replace "the amount" with The amount.

Page 11 line 26, replace "three-dimensional space and" with three-dimensional space, however, when the above-mentioned operation is executed,.

using any special spectacles, enables to be used in circumstances where display devices are difficult in use and enables to be observed by a lot of people simultaneously with one display device, integral photographic systems have been known.

As shown in FIG.6 this method employs an image display means 3 arranged on the side of a surface 2b formed by center points of curvatures of convex surfaces of a convex lens array 2 where a plurality of convex lenses 2a are arranged, and employs an image forming means (not shown in the figure) to form images on the image display device. A liquid crystal display device, a Brown tube display device, a plasma display device, liquid crystal projector or a film projector with screen, or a printed image or developed film image etc. may be used as the image display means 3.

The convex lens array 2 comprises a plurality of convex lenses 2a and since it resembles a compound eye of an insect, it is called a fly eye lens plate or a compound eye lens. These convex lenses 2a may be arranged in a lattice configuration as shown in FIG.7A or arranged in a hexagonal configuration as shown in FIG.7B.

Object images shot by cameras and the like or computer generated two- or three-dimensional characters or graphics etc. can be used as objects to be displayed.

In order to form an image on the image display means 3 by calculation with the aid of an image forming means (not shown in drawings), a point on the image display means 3 formed by a projected light irradiated from a randomly selected point on an object image to be displayed in a predetermined three-dimensional space and passing through a center point Cj of the curvature of the convex surface of the convex lens 2a, is calculated as shown in FIG.8. A projected image on the image display means is formed by repeating these calculations on all points on the object image to be displayed passing through center points Cj of the curvatures of convex lenses 2a.

The projected image on the image display means 3, originated from the object image 4 to be displayed, which pass through the center points Cj of curvatures of convex lenses 2a, is displayed for example on a liquid crystal display device and the projected image heads for a predetermined three-dimensional space when the image display means 3 is irradiated by a back light 6 from the right side as shown in FIG.9. A plurality of rays R corresponding to respective points to be projected in the three-dimensional space are converged one point to form a new apparent light spot O which an observer W can observe as a three-dimensional image.

As shown in FIG.10, in place of the lens array, three-dimensional image display device 11 may comprise a light shielding plate 12 where a plurality of pin holes 12a, an image displaying means 13 arranged a predetermined distance from the light shielding plate 12 and an image forming means (not shown in FIG.10) for forming images on the image displaying means 13.

A plurality of pin holes 12a are perforated on the light shielding plate 12, where pin holes 12a may be arranged either in a lattice configuration as shown in FIG.11A or in a honey comb configuration as shown in FIG.11B.

The image can be also displayed in the predetermined three-dimensional space by utilizing the light shielding plate 12 in the same way as the above-mentioned convex lens array 2, by adjusting pin holes 12a at positions corresponding to curvature centers Cj of the convex surfaces of convex lens 2a.

As a conventional art regarding the above-mentioned integral photography, the Japanese laid open patent No. 4-133049 discloses a method to record three-dimensional still images, where the convex lens array is used for displaying three-dimensional images and an XYZ plotter and recording media for recording three-dimensional still pictures on the recording media by moving a point light source mechanically, are disclosed.

The Japanese laid open patent No. 10-186275 where the above-mentioned integral photography is employed, discloses a three-dimensional

display device capable of being manufactured easily, without having distinct respective lens marks, having excellent focusing performance and displaying three-dimensional images in a state keeping enough brightness. The three-dimensional display device has a feature that gaps among a plurality lens elements comprising a lens array, are shielded by light shielding members.

In these conventional three-dimensional display devices, images to be displayed on the image display means 3 are formed through calculations executed by the image forming means in a way shown in FIG.8. However, since the amount to be calculated correspond to a product of the number of points not only on the surface but including inside of the object comprising the object image to be displayed in the predetermined three-dimensional space and the number of lenses on the lens array (or the number of pin holes on the light shielding plate) and, since an additional hidden surface process (a process to remove actually unobserved points) is necessary, a huge amount of calculation is required. Since moving pictures requires forming a lot of images at a high rate, a large scaled three-dimensional display device is required, consequently it requires a higher cost.

Disclosure of the Invention

The present invention is carried out in view of the above-mentioned conventional problems so as to provide a three-dimensional display device capable of forming images at a high rate by remarkably reducing the amount of calculation.

Other objective of the present invention is to provide a three-dimensional display device with a large display screen and a three-dimensional display device capable of displaying more vivid images.

In order to attain the above-mentioned objectives, the three-dimensional display device according to the present invention comprises: the convex lens array where a plurality of convex lenses are arranged, the image display

means arranged on or near a focal plane of the lens array; an operating means to calculate only the furthest point from the image display means among points intersecting the object image to be displayed determined by the operating means, on a light starting from a pixel on the image display means, passing through only the center of the curvature of the convex surface of a plurality of the respective convex lenses among lights heading for a plurality of the convex lenses and heading toward the object image to be displayed in the predetermined three-dimensional space; and an image controlling means for instructing to display corresponding pixels on the image display means based on the image information calculated the operating means.

The three-dimensional display device according to the present invention comprises: the light shielding plate where a plurality of pin holes are arranged; the image display means arranged at the predetermined distance from the light shielding plate; the operating means to calculate only the furthest point from the image display means among points intersecting the object image to be displayed determined by the operating means, on a light starting from the pixel on the image display means, passing through a plurality of respective pin holes among lights heading for the light shielding plate and heading toward the object image to be displayed in the predetermined three-dimensional space; and the image controlling means for instructing to display corresponding pixels on the image display means based on the image information calculated the operating means.

Since the amount to be calculated by the operating means is, for example, a product of pixels on the image display means and a resolution including pixels not only on the surface but also along a vertical direction of the object image to be displayed in the predetermined three-dimensional space, the amount to be calculated according to the present invention is capable of reducing to a large extent by employing the above-mentioned three-dimensional image display device. And since additional hidden surface

process is simultaneously executed according to the present method, the amount to be calculated is further reduced so that images can be formed at a high rate.

When the convex lens array and the light shielding plate where pin holes

Amended Sheet in Spec.

are arranged, are compared, the latter is easier to manufacture, but the convex lens array is capable of accumulating light so that more bright images are obtained.

A three-dimensional display device having a constitution of a plurality of image display means and a plurality of the above-mentioned lenses or a constitution of a plurality of image display means and a plurality of the above-mentioned pin holes, namely, one image display means is arranged for a plurality of respective convex lenses or pin holes, can be arranged. In addition a plurality of the above-mentioned image display means can be arranged for one above-mentioned lens array or one light shielding plate.

Since a plurality of the image display means can be arranged in the three-dimensional image display device, a image display screen having any dimension can be attained so that a three-dimensional image display device having a large scaled screen can be provided.

A diffusing plate can be arranged between a point determined by lines irradiated from respective pixels of the image display means and passing through respective center points of the curvatures of the convex surfaces of a plurality of the convex lenses or respective pin holes intersect each other and a point where the observer's eyes are positioned.

By introducing the diffusing plate between the image displayed in the three-dimensional space and the observer even when observer's eyes are not positioned on the lines irradiated from respective pixels of the image display means and passed through respective center points of the curvatures of the convex surfaces of a plurality of the convex lenses or respective pin holes, other points on the image display means not on the above mentioned lines are also observed so that a resolution of the projected image in the predetermined three-dimensional space is enhanced because an apparent size of pixels become smaller than a diameter of the convex lens or the pin hole.

Moving pictures can be displayed in the predetermined three-

dimensional space by successively calculating with the operating means and

predetermined three-dimensional space is located above the convex lens array.

Here Pi is defined as the furthest point among points in the object image 4 to be displayed, on the intersecting straight line L starting from a pixel Dij on the image display means 3, passing through a center point Cj of a curvature of a convex surface of a convex lens 2a and directing toward the object image 4 to be displayed.

A toe of a perpendicular line to the surface 2b determined by center points of curvatures of convex surfaces of convex lenses 2a is defined as "Qj". And a toe of a perpendicular line from the center point Cj of the curvature of the convex surface of the convex lens 2a, to the image display means 3 is defined as "Cj'". Since a triangle CjCj'Dij and a triangle PiQjCj are similar figures, the following equation is derived:

$$CjQj : PiQj = DijCj' : h$$

Since DijCj' is determined by a geometrical relation between the lens array 2 and the image display means 3, when either CjQj or PiQj is measured, remaining either of them can be calculated.

When the object image 4 to be displayed is scanned by stepwise vertical planes from left side in FIG.1, Pi is determined by the relation between intersecting point in the object to be displayed formed by vertical planes and the above-mentioned straight line L. Thus, PiQj is derived from the determined Pi. Consequently, CjQj in FIG.2 can be calculated based on the above-mentioned equation from obtained PiQj.

The amount of operation by the operating means is a product of pixels on the image display means 3 and a resolution along a depth direction of the object image to be displayed in the three-dimensional space, however, when the above-mentioned operation is executed, the amount of the calculation is remarkably reduced compared with conventional ways because only actually observed points are calculated and hidden surface process is also executed simultaneously.

AMENDED CLAIMS

[Received by the International Bureau on 19 July, 2000 (19.07.00);
Original claims 1 and 2 are replaced by new claims 1 and 2.]

1. (Amended) A three-dimensional display device comprising:

a convex lens array where a plurality of convex lenses are arranged,

an image display means arranged on or near a focal plane of said convex lens array,

an operating means to calculate only the farthest point from said image display means among points intersecting an object image to be displayed determined by said operating means, on a light starting from a pixel on said image display means passing through only the center of the curvature of the convex surface of a plurality of said respective convex lens among lights heading for a plurality of said convex lenses and heading toward said object image to be displayed in the predetermined three-dimensional space, and

an image controlling means for instructing to display corresponding pixels on said image display means based on the image information calculated by said operating means.

2. (Amended) A three-dimensional display device comprising:

a light shielding plate where a plurality of pin holes are arranged,

an image display means arranged at a predetermined distance from the light shielding plate,

an operating means to calculate only the farthest point from said image display means among points intersecting an object image to be displayed determined by said operating means, on a light starting from a pixel on said image display means, passing through a plurality of said respective pin holes among lights heading for said light shielding plate and heading toward said object image to be displayed in the predetermined three-

dimensional space, and

an image controlling means for instructing to display corresponding pixels on said image display means based on the image information calculated by said operating means.

3. The three-dimensional display device according to claim 1 or claim 2, wherein;

a plurality of said image display means are respectively arranged for a plurality of said lenses or for a plurality of said pin holes, and

said three-dimensional image display device comprises a plurality of said image display means and a plurality of said convex lenses or comprises a plurality of said image display means and a plurality of said pin holes.

4. The three-dimensional display device according to claim 1 or claim 2, wherein:

a plurality of said image display means are arranged for one said convex lens array or for one said light shielding plate.

5. The three-dimensional display device according to either one of the claims 1 to 4, wherein:

a diffusing plate is arranged between a point determined by lines from respective pixels of said image display means and passed through the center points of the curvatures of the convex surfaces of a plurality of said convex lenses or said pin holes intersect each other and a position where observer's eyes are located.

6. The three-dimensional image display device according to either one of the claims 1 to 5, wherein:

a moving picture is displayed in said predetermined three-dimensional space based on the successive calculation by said operating means and simultaneous successive instructions from said controlling means.

STATEMENT UNDER ARTICLE 19(1)

Claim 1 is characterized that the operating means to calculate only the farthest point from said image display means among points intersecting the object image to be displayed determined by the operating means, on the light starting from a pixel on the image display means passing through only the center of the curvature of the convex surface of a plurality of respective convex lens among lights heading for a plurality of convex lenses and heading toward the object image to be displayed in the predetermined three-dimensional space so as to reduce the amount of operation remarkably and to enable the image display device to reproduce at higher rate.

Also claim 2 is characterized that the operating means to calculate only the farthest point from the image display means among points intersecting the object image to be displayed determined by said operating means, on the light starting from a pixel on the image display means, passing through a plurality of respective pin holes among lights heading for said light shielding plate and heading toward the object image to be displayed in the predetermined three-dimensional space, consequently, this claim attains the same effects as claim 1.

Any cited references do not disclose the above-mentioned technical features. The cited reference JP11-174377 has a technical feature same as claims 1 and 2 of the present invention characterized that calculating the farthest points when intersecting points of lights heading for the object image to be displayed are determined. However, all farthest points are calculated in the cited reference. Which is different from the technical idea of the present invention such that the calculation is executed on lights passing through only centers of convex surfaces of convex lenses.

AMENDED CLAIMS

[Received by the Japanese Patent Office on 22 January, 2001 (22.01.01).
Original claims 1 and 2 are replaced by new claims 1 and 2.]

1. (Twice amended) A three-dimensional display device comprising:

a convex lens array where a plurality of convex lenses are arranged,

an image display means arranged on or near a focal plane of said convex lens array,

an operating means to calculate only the farthest point from said image display means among points intersecting an object image to be displayed determined by said operating means including not only points on the surface but also in the depth direction of the object, on a light starting from a pixel on said image display means passing through only the center of the curvature of the convex surface of a plurality of said respective convex lens among lights heading for a plurality of said convex lenses and heading toward said object image to be displayed in the predetermined three-dimensional space, and

an image controlling means for instructing to display corresponding pixels on said image display means based on the image information calculated by said operating means.

2. (Twice amended) A three-dimensional display device comprising:

a light shielding plate where a plurality of pin holes are arranged,

an image display means arranged at a predetermined distance from the light shielding plate,

an operating means to calculate only the farthest point from said image display means among points intersecting an object image to be displayed determined by said operating means including not only points on the surface but also in the depth direction of the object, on a light starting from a pixel on said image display means, passing through a plurality of said

respective pin holes among lights heading for said light shielding plate and heading toward said object image to be displayed in the predetermined three-dimensional space, and

an image controlling means for instructing to display corresponding pixels on said image display means based on the image information calculated by said operating means.

3. The three-dimensional display device according to claim 1 or claim 2, wherein:

a plurality of said image display means are respectively arranged for a plurality of said lenses or for a plurality of said pin holes, and

said three-dimensional image display device comprises a plurality of said image display means and a plurality of said convex lenses or comprises a plurality of said image display means and a plurality of said pin holes.

4. The three-dimensional display device according to claim 1 or claim 2, wherein:

a plurality of said image display means are arranged for one said convex lens array or for one said light shielding plate.

5. The three-dimensional display device according to either one of the clams 1 to 4, wherein:

a diffusing plate is arranged between a point determined by lines from respective pixels of said image display means and passed through the center points of the curvatures of the convex surfaces of a plurality of said convex lenses or said pin holes intersect each other and a position where observer's eyes are located.

6. The three-dimensional image display device according to either one of the claims 1 to 5, wherein:

a moving picture is displayed in said predetermined three-dimensional space based on the successive calculation by said operating means and simultaneous successive instructions from said controlling means.

REFUTATION TO THE FIRST OPINION

The first opinion of the international preliminary examination stated that the calculating method for limiting lights passing through an aperture and center of curvature of a lens is merely a fundamental analytical procedure in the geometrical optics.

We admit the statement is as a matter of course and the above-mentioned calculating method itself can not constitute an invention.

The most important point in the present invention is the calculating method of the displayed image on the screen positioned at the opposite side of the respective lens on the lens array through which the three-dimensional image consisting of a set of huge amount of pixels including not only on the surface but also the depth direction of the object, pass and is projected onto the display screen.

In the conventional calculating method, at first intersecting points on the surface of the display screen positioned at the opposite side of the lenses, of the lights irradiated from center points of respective pixels, which consist three-dimensional image, passing through centers of lenses and projected on the display screen are calculated and then the hidden surface removal is executed so that it takes a long time before finishing the huge amount of calculation as follows.

Example of the conventional calculation

The object image: 1,000,000 voxels in the three-dimensional space of 256 $\times 256 \times 256$

The display means: a resolution of $1,000 \times 1,000$

The lens array 100×100 lenses

Amount of calculation: number of voxels $\times$ number of lenses

$= 1,000,000 \times 100 \times 100 = 10,000,000,000$

On the other hand the calculating method according to the present invention utilizes the fact that the display means consist a set of discontinuous pixels.

Namely, the calculating method according to the present invention is characterized: a line connecting the center of a pixel on the display means and the center of a lens, is extended toward the three-dimensional image, and is scanned from the three-dimensional image side repeatedly. Information regarding the first point where the scanned line intersecting the three-dimensional image of the object to be displayed, is displayed on the pixel on the display means. Amount of calculation is remarkably reduced in the present method.

Example of the calculation according to the present invention

Maximum amount of calculation on the same condition as the above conventional method: number of pixels on the display means $\times$ a resolution along the depth direction of the three-dimensional image data = $1,000 \times 1,000 \times 256 = 256,000,000 << 10,000,000,000$ (conventional method)

The Examiner's statement that calculating method for limiting lights passing through an aperture and center of curvature of a lens is merely a fundamental analytical procedure in the geometrical optics, indicates that the method is utilized not only in the present invention but also in the conventional calculation. Therefore it is needless to say that the method is not patentable.

6/PRT

09/937113
JC03 Rec'd PCT/PTO 20 SEP 2001

SUBSTITUTE SPECIFICATION AND AMENDED CLAIMS

THREE-DIMENSIONAL IMAGE DISPLAY DEVICE

Field of the Invention

[0001] The present invention relates to a three-dimensional image display device particularly applicable to the following fields.

Medicine:

Diagnosis through images, Operation aid, Remote diagnosis, Informed consent etc.

Advertisement:

Bill board, Product sample/display, Demonstration etc.

Art:

Art object, Painting, Graphic art, the Interior, Exhibition in art galleries/museums etc.

Entertainment:

Movie, Game, various Playing machines, Exhibition at attractions/theme pavilions and the like, Training and exercise in sports etc.

Information/Multi-media:

TV broadcast, TV conference, TV phone, Virtual reality,

the Internet etc.

Simulation:

Driving exercise and operation planning for cars, airplanes, ships and space ships etc.

Design Aid:

Modeling, Strength test, Destruction test etc.

Educational aid:

Specimen of human bodies, Biological objects and DNA structures, Celestial bodies, Map etc.

Miscellaneous:

Book, Model, Toy, Souvenir etc.

Background of the Invention

[0002] Numerous display devices for displaying motion or still pictures in a space have been developed, but most of them show different pictures viewed from the right and left eyes so as to add stereo feeling to these pictures. In these devices, one image is not displayed in the space but taking a parallax into consideration, two different images viewed from right and left eyes are displayed in these devices so that observers can recognize these right and left eye views as one image, which merely gives observers stereo feelings.

[0003] Since the parallax is determined by a distance between right and left eyes, it is naturally different from each observer. Therefore when two different two-dimensional images are recognized as one three-dimensional image, but it is recognized differently by respective observers.

[0004] In the above-mentioned method where two different two-dimensional images are recognized as one three-dimensional image, observers merely observe the same one three-dimensional image from a different angle, but do not observe a different corresponding three-dimensional image from that angle.

[0005] In addition, since in the above-mentioned method different two-dimensional images having an artificial parallax viewed with right and left eyes are forcibly recognized as a three-dimensional image, there is a problem that observers are exhausted when trying to recognize the three-dimensional image.

[0006] A three-dimensional displaying method using integral photographic systems have been known. This method enables observers to recognize an image as a stereo image regardless of parallaxes, positions, observing directions, observing with one eye or two eyes of the observers without using any special spectacles. The method is enabled to be used in circumstances where the display devices are difficult in use and which are enabled to be observed by numerous people simultaneously with one display device,.

[0007] As shown in FIG.6, this method employs an image display 3 arranged on the side of a surface 2b formed by center points of curvatures of convex surfaces of a convex lens array 2 where a plurality of convex lenses 2a are arranged, and employs an image forming means (not shown in the figure) to form images on the image display device. A liquid crystal display device, a Brown tube display device, a plasma display device, liquid crystal projector or a film projector with screen, or a printed image or developed film image etc. may be used as the image display 3.

[0008] The convex lens array 2 comprises a plurality of convex lenses 2a and since it resembles a compound eye of an insect, it is called a fly eye lens plate or a compound eye lens. These convex lenses 2a may be arranged in a lattice configuration as shown in FIG.7A or arranged in a hexagonal configuration as shown in FIG.7B.

[0009] Object images shot by cameras and the like or computer generated two- or three-dimensional characters or graphics etc. can be used as objects to be displayed.

[0010] In order to form an image on the image display 3 by calculation with the aid of an image forming means (not shown in drawings), a point on the image display 3

formed by a projected light irradiated from a randomly selected point on an object image to be displayed in a predetermined three-dimensional space and passing through a center point Cj of the curvature of the convex surface of the convex lens 2a, is calculated as shown in FIG.8. A projected image on the image display means is formed by repeating these calculations on all points on the object image to be displayed passing through center points Cj of the curvatures of convex lenses 2a.

[0011] The projected image on the image display 3, originated from the object image 4 to be displayed, which pass through the center points Cj of curvatures of convex lenses 2a, is displayed for example on a liquid crystal display device and the projected image heads for a predetermined three-dimensional space when the image display 3 is irradiated by a back light 6 from the right side as shown in FIG.9. A plurality of rays R corresponding to respective points to be projected in the three-dimensional space are converged one point to form a new apparent light spot O which an observer W can observe as a three-dimensional image.

[0012] As shown in FIG.10, in place of the lens array, three-dimensional image display device 11 may comprise a light shielding plate 12 where a plurality of pin holes 12a, an image displaying means 13 arranged a predetermined distance from the light shielding plate 12 and an image forming means (not shown in FIG.10) for forming images on the image displaying means 13.

[0013] A plurality of pin holes 12a are perforated on the light shielding plate 12, where pin holes 12a may be arranged either in a lattice configuration as shown in FIG.11A or in a honey comb configuration as shown in FIG.11B.

[0014] The image can be also displayed in the predetermined three-dimensional space by utilizing the light shielding plate 12 in the same way as the above-mentioned

convex lens array 2, by adjusting pin holes 12a at positions corresponding to curvature centers Cj of the convex surfaces of convex lens 2a.

[0015] As a conventional art regarding the above-mentioned integral photography, the Japanese laid open patent No. 4-133049 discloses a method to record three-dimensional still images, where the convex lens array is used for displaying three-dimensional images and an XYZ plotter and recording media for recording three-dimensional still pictures on the recording media by moving a point light source mechanically, are disclosed.

[0016] The Japanese laid open patent No. 10-186275 where the above-mentioned integral photography is employed, discloses a three-dimensional display device capable of being manufactured easily, without having distinct respective lens marks, having excellent focusing performance and displaying three-dimensional images in a state keeping enough brightness. The three-dimensional display device has a feature that gaps among a plurality lens elements comprising a lens array, are shielded by light shielding members.

[0017] In these conventional three-dimensional display devices, images to be displayed on the image display 3 are formed through calculations executed by the image forming means in a way shown in FIG.8. However, since the amount to be calculated correspond to a product of the number of points not only on the surface but also including inside of the object comprising the object image to be displayed in the predetermined three-dimensional space and the number of lenses on the lens array (or the number of pin holes on the light shielding plate) and, since an additional hidden surface process (a process to remove actually unobserved points) is necessary, a huge amount of calculation is required. Since moving pictures

requires forming many images at a high rate, a large scaled three-dimensional display device is required, and consequently requiring a higher cost.

Disclosure of the Invention

[0018] The present invention is carried out in view of the above-mentioned conventional problems so as to provide a three-dimensional display device capable of forming images at a high rate by remarkably reducing the amount of calculation.

[0019] Other objective of the present invention is to provide a three-dimensional display device with a large display screen and a three-dimensional display device capable of displaying more vivid images.

[0020] In order to attain the above-mentioned objectives, the three-dimensional display device according to the present invention comprises: the convex lens array where a plurality of convex lenses are arranged, the image display means arranged on or near a focal plane of the lens array; an operating means to calculate only the furthest point from the image display means among points intersecting the object image to be displayed determined by the operating means, on a light starting from a pixel on the image display means, passing through only the center of the curvature of the convex surface of a plurality of respective convex lenses among lights heading for a plurality of the convex lenses and heading toward the object image to be displayed in the predetermined three-dimensional space; and an image controlling means for instructing the display of corresponding pixels on the image display means based on the image information calculated by the operating means.

[0021] The three-dimensional display device according to the present invention comprises: the light shielding plate where a plurality of pin holes are arranged; the image display means arranged at the predetermined distance from the light

shielding plate; the operating means to calculate only the furthest point from the image display means among points intersecting the object image to be displayed determined by the operating means, on a light starting from the pixel on the image display means, passing through a plurality of respective pin holes among lights heading for the light shielding plate and heading toward the object image to be displayed in the predetermined three-dimensional space; and the image controlling means for instructing to display corresponding pixels on the image display means based on the image information calculated the operating means.

[0022] Since the amount to be calculated by the operating means is, for example, a product of pixels on the image display means and a resolution including pixels not only on the surface but also along a vertical direction of the object image to be displayed in the predetermined three-dimensional space, the amount to be calculated according to the present invention is capable of reducing to a large extent by employing the above-mentioned three-dimensional image display device. And since additional hidden surface process is simultaneously executed according to the present method, the amount to be calculated is further reduced so that images can be formed at a high rate.

[0023] When the convex lens array and the light shielding plate where pin holes are arranged, are compared, the latter is easier to manufacture, but the convex lens array is capable of accumulating light so that more bright images are obtained.

[0024] A three-dimensional display device having a constitution of a plurality of image display means and a plurality of the above-mentioned lenses or a constitution of a plurality of image display means and a plurality of the above-mentioned pin holes, namely, one image display means is arranged for a plurality of respective convex

lenses or pin holes, can be arranged. In addition a plurality of the above-mentioned image display means can be arranged for one above-mentioned lens array or one light shielding plate.

[0025] Since a plurality of the image display means can be arranged in the three-dimensional image display device, a image display screen having any dimension can be attained so that a three-dimensional image display device having a large scaled screen can be provided.

[0026] A diffusing plate can be arranged between a point determined by lines irradiated from respective pixels of the image display means and passing through respective center points of the curvatures of the convex surfaces of a plurality of the convex lenses or respective pin holes intersect each other and a point where the observer's eyes are positioned.

[0027] By introducing the diffusing plate between the image displayed in the three dimensional space and the observer even when the observer's eyes are not positioned on the light irradiated from respective pixels of the image display means and passed through respective center points of the curvatures of the convex surfaces of a plurality of the convex lenses or respective pin holes, other points on the image display means not on the above mentioned light are also observed so that a resolution of the projected image in the predetermined three-dimensional space is enhanced because an apparent size of pixels become smaller than a diameter of the convex lens or the pin hole.

[0028] Moving pictures can be displayed in the predetermined three-dimensional space by successively calculating with the operating means and successively instructing from the controlling means.

[0029] According to the present invention, since images can be formed at the high rate as mentioned above, more vivid images can be displayed even when the moving picture is displayed. An apparent resolution of the moving picture can be improved, since an afterimage effect of observers' eyes can be utilized.

Brief Description of Drawings

[0030] FIG.1 is a schematic diagram for explaining a calculating method by the operating means in a first embodiment of the three-dimensional display device according to the present invention.

[0031] FIG.2 is a schematic diagram for explaining the calculating method by the operating means in the first embodiment of the three-dimensional display device according to the present invention.

[0032] FIG.3 is a schematic diagram showing a second embodiment of the three-dimensional display device according to the present invention, where one convex lens is arranged to one image display means.

[0033] FIG.4 is a schematic diagram showing a third embodiment of the three-dimensional display device according to the present invention, where one pin hole is arranged to one image display means.

[0034] FIGs.5A and 5B are a schematic diagram showing a fourth embodiment of the three-dimensional display device according to the present invention, where FIG.5A shows the three-dimensional display device without the diffusing plate and FIG.5B shows the three-dimensional display device equipped with the diffusing plate.

[0035] FIG.6 is a schematic diagram showing a conventional embodiment of the three-dimensional display device employing the convex lens array where a plurality of

convex lenses are arranged.

[0036] FIGs.7A and 7B are schematic diagrams showing configurations of convex lenses in the three-dimensional display device in FIG.6, where FIG.7A shows a lattice configuration and FIG.7B shows a honey comb configuration.

[0037] FIG.8 is a schematic diagram for explaining a forming method of object images to be displayed in the three-dimensional space in the conventional three-dimensional display device, projected on the image display means via convex lens array, by calculation.

[0038] FIG.9 is a schematic diagram for explaining a displaying method in the three-dimensional space by employing the conventional three-dimensional display device.

[0039] FIG.10 is a schematic diagram showing another conventional example of the three-dimensional display device employing the light shielding plate where a plurality of pin holes are arranged.

[0040] FIGs.11A and 11B are schematic diagrams showing configurations of convex lenses in the three-dimensional display device in FIG.10, where FIG.11A shows a lattice configuration and FIG.11B shows a honey comb configuration.

Detailed Description of Preferred Embodiments

[0041] Hereinafter embodied examples of the three-dimensional display devices according to the present invention are described by referring drawings.

[0042] As a first embodied example, a three-dimensional display device shown in FIG.6 comprising the lens array 2 where a plurality of convex lenses 2a are arranged and the image display 3 arranged at the side of the surface 2b determined by center points of curvatures of convex surfaces of convex lenses 2a of the convex lens

array 2 is explained.

[0043] In the same way as the conventional display devices, the liquid crystal display device, the Brown tube image display device, the plasma display device, the liquid crystal or film projector with the screen, or the printed or developed film image etc. can be employed as the three-dimensional display device 3. Two-dimensional or three-dimensional character or graphic images formed by photographs of real objects and computer graphics can be used as objects to be displayed.

[0044] In addition to the above-mentioned convex lens array 2 and image display 3, the operating means and the image controlling means, both are not shown in the figure, are equipped in the three-dimensional display device according to the present invention.

[0045] As shown in FIG.1, the operating means calculates a farthest point Pi from the three-dimensional display 3 among points in an object image 4 to be displayed, on an intersecting straight line L starting from respective pixel Dij on the image display 3, passing through respective center points Cj of the curvatures of respective convex surfaces of a plurality of convex lenses 2a and directing toward the object image 4 to be displayed. The image controlling means instructs to display image information of the point Pi calculated by the operating means, onto the corresponding pixel Dij of the image display 3.

[0046] A whole image to be displayed on the image display 3 is formed by executing the above-mentioned procedure over the whole pixels on the image display 3.

[0047] FIG.2 is a schematic diagram showing a calculating method for selecting the farthest point Pi from the three-dimensional display 3 among points in the object image 4 to be displayed, on the intersecting straight line L starting from respective

pixel Dij on the image display 3, passing through respective center points Cj of the curvatures of respective convex surfaces of a plurality of convex lenses 2a and directing toward the object image 4 to be displayed.

[0048] The image display 3 is arranged below the convex lens array 2, where a distance between them is defined as "h" and a center point of the curvature of the convex surface of the convex lens 2a is defined as "Cj". It is assumed that the image to be displayed (corresponds to 4 in FIG.1) in the predetermined three-dimensional space is located above the convex lens array.

[0049] Here Pi is defined as the farthest point among points in the object image 4 to be displayed, on the intersecting straight line L starting from a pixel Dij on the image display 3, passing through a center point Cj of a curvature of a convex surface of a convex lens 2a and directing toward the object image 4 to be displayed.

[0050] A toe of a perpendicular line to the surface 2b determined by center points of curvatures of convex surfaces of convex lenses 2a is defined as "Qj". And a toe of a perpendicular line from the center point Cj of the curvature of the convex surface of the convex lens 2a, to the image display 3 is defined as "Cj'". Since a triangle CjCj'Dij and a triangle PiQjCj are similar figures, the following equation is derived:

[0051] CjQj : PiQj = DijCj' : h

[0052] Since DijCj' is determined by a geometrical relation between the lens array 2 and the image display 3, when either CjQj or PiQj is measured, remaining either of them can be calculated.

[0053] When the object image 4 to be displayed is scanned by stepwise vertical planes from left side in FIG.1, Pi is determined by the relation between intersecting point in the object to be displayed formed by vertical planes and the above-mentioned

straight line L. Thus, PiQj is derived from the determined Pi. Consequently, CjQj in FIG.2 can be calculated based on the above-mentioned equation from obtained PiQj.

[0054] The amount of operation by the operating means is a product of pixels on the image display 3 and a resolution along a depth direction of the object image to be displayed in the three-dimensional space. However, when the above mentioned operation is executed, the amount of calculation is remarkably reduced compared with conventional methods because only actually observed points are calculated and a hidden surface process is also executed simultaneously.

[0055] One example of apparatus to carry out the above-mentioned method, namely, an actual constitution of the operating means and the image controlling means, is a combination of CT (Computerized tomography) which takes three-dimensional tomographic images, and a personal computer which execute above-mentioned operation so as to obtain image data to be displayed on the three-dimensional image display 3. When the convex lens array is placed in front of the liquid crystal display device used as the image display 3 on which the obtained image data are displayed, the above-mentioned three-dimensional tomographic image is displayed in the predetermined three-dimensional space situated in front of the convex lens array.

[0056] In the same way as the conventional methods in place of the convex lens array, the light shielding plate 12 where a plurality of pin holes 12a are arranged as shown in FIG.10 can be used together with the above-mentioned operational means and the image controlling means so that the three-dimensional display device according to the present invention is constituted. Since effects of the pin holes 12a in place of

the convex lens array 12 are the same as in the conventional methods, further explanation is omitted.

[0057] Hereinafter the second embodiment of the three-dimensional display device according to the present invention is explained by referring FIG.3.

[0058] In the above mentioned first embodiment one image display device is used for one convex lens array 2 where a plurality of convex lenses are arranged, but individual image display devices 3 (3A to 3D) are arranged respectively to a plurality of convex lenses 2a in this embodiment so that the three-dimensional display device 1 comprises a plurality of image display 3 (3A to 3D) and a plurality of convex lenses 2a. When this arrangement is employed, an image display surface having desired size can be constituted and the three-dimensional image display device 3 having a large display screen can be provided.

[0059] As the third embodiment of the three-dimensional display device shown in FIG.4 according to the present invention, individual image display devices 13 (13A to 13D) are arranged respectively to a plurality of pin holes 12a so that the three-dimensional display device 11 comprises a plurality of image display means 13 (13A to 13D) and a plurality of convex lenses 12a, which attains the same effect as the second embodiment.

[0060] By arranging a plurality of image display 3 (or 13) for at least one convex lens array 2 or light shielding plate 12 in stead of one to one arrangement of the convex lens 2 or the pin hole 12a for the image display 3 (or 13) as described in the embodiments 2 and 3, an image display surface having desired size can be constituted and the three-dimensional image display device 3 having the large display screen can be provided.

[0061] As shown in FIG.5B, a diffusing plate 5 such as a ground glass plate and the like is placed between a point O, where straight lines from respective pixels on the image display 3 toward the object image to be displayed in the predetermined three-dimensional space via respective center points Cj of curvatures of convex surfaces of convex lenses 2a arranged on the lens array 2 intersect each other, and a position where observer W's eyes are located.

[0062] As shown in FIG.5A when the diffusing plate 5 is not placed, the observer W observes only points on the lines connected between observer W's eyes and respective center points Cj of curvatures of convex surfaces of convex lenses 2a so that only one pixel is observed for one convex lens 2a, consequently, an apparent pixel size corresponds to the diameter of the convex lens 2a.

[0063] On the other hand when the diffusing plate 5 is placed as shown in FIG.5B, the apparent pixel size looks smaller than the diameter of the convex lens 2a, which increase a resolution of a projector, because the observer W can observe other points not on the lines connected between observer W's eyes and respective center points Cj of curvatures of convex surfaces of convex lenses 2a, due to diffused lights which reach into observer W's eyes as synthesized lights S.

[0064] Although not shown in drawings, the above mentioned diffusing plate 5 can be used in the case of the light shielding plate 12 in place of the convex lens array 2. In this case, the apparent pixel size looks smaller than a pin hole spacing, which increase a resolution projected in the predetermined three-dimensional space, because through the diffusing plate 5 the observer W can observe other points not on lines from respective pixels on the image display means toward object image to be displayed in the predetermined three-dimensional space via a plurality of pin

holes even when observer W's eyes are not on these lines.

[0065] Moving pictures can be displayed in the predetermined three-dimensional space when the calculation by the above-mentioned operating means and instructions by the image controlling means are successively executed. Since the residual image effects in the human eyes are attained by moving pictures, the apparent resolution can be improved.

[0066] As explained above, images can be formed at higher rate, since the amount of operation for forming images is remarkably reduced by the present invention compared with conventional methods. Due to reduced operating amount, a smaller scaled three-dimensional display device can be provided, as a result, a less expensive three-dimensional display device can be provided.

[0067] In addition to the above-mentioned effects the present invention is capable of constituting an image display screen having any desired size and providing the three-dimensional display device having a large scaled display screen.

[0068] Further, the apparent pixel size can be reduced to less than the diameter of the convex lens or the pin hole spacing, consequently the three-dimensional display device capable of attaining higher resolutions in images projected in the predetermined three-dimensional space can be provided.

[0069] The three-dimensional image display device capable of displaying more vivid moving pictures can be provided when the calculation by the operating means and instructions by the image controlling means are successively executed, because images can be formed at high rate even when moving pictures are displayed in the predetermined three-dimensional space.

[0070] The three-dimensional image display device according to the present invention

can be applied to the following fields, can provide more vivid images and can provide less expensive systems.

[0071] Medicine:

[0072] Diagnosis through images, Operation aid, Remote diagnosis, Informed consent etc.

[0073] Advertisement:

[0074] Bill board, Product sample/display, Demonstration etc.

[0075] Art:

[0076] Art object, Painting, Graphic art, the Interior, Exhibition in art galleries/museums etc.

[0077] Entertainment:

[0078] Movie, Game, various Playing machines, Exhibition at attractions/theme pavilions and the like, Training and exercise in sports etc.

[0079] Information/Multi-media:

[0080] TV broadcast, TV conference, TV phone, Virtual reality,

[0081] the Internet etc.

[0082] Simulation:

[0083] Driving exercise and operation planning for cars, airplanes, ships and space ships etc.

[0084] Design Aid:

[0085] Modeling, Strength test, Destruction test etc.

[0086] Educational aid:

[0087] Specimen of human bodies, Biological objects and DNA structures, Celestial bodies, Map etc.

[0088] Miscellaneous:

[0089] Book, Model, Toy, Souvenir etc.

What is claimed is

1. A three-dimensional display device comprising:

a convex lens array including a plurality of convex lenses having a focal plane, each lens having a convex surface;

image display means arranged on or adjacent to the focal plane of said convex lens array;

operating means for calculating only the furthest point from said image display means among points intersecting an object image to be displayed determined by the operating means including not only points on the convex surface of each of the lenses of the array, but also in a depth direction of the object, on light starting from a pixel on said image display means passing through only the center of the curvature of the convex surfaces of the plurality of said respective convex lenses among light rays heading for a plurality of said convex lenses and heading toward said object image to be displayed in the predetermined three-dimensional space; and

image controlling means responsive to the operating means for controlling the display of corresponding pixels on said image display means based on the image information calculated by said operating means.

2. A three-dimensional display device comprising:

a light shielding plate having a plurality of pin holes;

image display means arranged at a predetermined distance from the light shielding plate;

operating means for calculating only the furthest point from said image display means among points intersecting an object image to be displayed determined by said

operating means including not only points on the surface of the plate but also in a depth direction of the object, on light starting from a pixel on said image display means, passing through a plurality of said respective pin holes among light rays heading for said light shielding plate and heading toward said object image to be displayed in the predetermined three-dimensional space, and

image controlling means for controlling the display of corresponding pixels on said image display means based on the image information calculated by said operating means.

3. The three-dimensional display device according to claim 1 or claim 2, wherein;

a plurality of said image display means are respectively arranged for a plurality of said lenses or for a plurality of said pin holes, and

said three-dimensional image display device comprising a plurality of said image display means and a plurality of said convex lenses or comprises a plurality of said image display means and a plurality of said pin holes.

4. The three-dimensional display device according to claim 1 or claim 2, wherein:

a plurality of said image display means are arranged for one said convex lens array or for one said light shielding plate.

5. The three-dimensional display device according to claim 1 or 2, including:

a diffusing plate arranged between a point determined by light from respective pixels of said image display means and passed through the center points of the curvatures of the convex surfaces of a plurality of said convex lenses or said pin holes

intersect each other and a position where observer's eyes are located.

6. The three-dimensional display device according to claim 3, including:

a diffusing plate arranged between a point determined by light from respective pixels of said image display means and passed through the center points of the curvatures of the convex surfaces of a plurality of said convex lenses or said pin holes intersect each other and a position where observer's eyes are located.

7. The three-dimensional display device according to claim 4, including:

a diffusing plate arranged between a point determined by light from respective pixels of said image display means and passed through the center points of the curvatures of the convex surfaces of a plurality of said convex lenses or said pin holes intersect each other and a position where observer's eyes are located.

8. The three-dimensional image display device according to claims 1 or 2, wherein:

a moving picture is displayed in said predetermined three-dimensional space based on the successive calculation by said operating means and simultaneous successive instructions from said controlling means.

ABSTRACT OF THE DISCLOSURE

[0090] A three-dimensional image display device capable of forming images at a higher rate is provided by reducing amount of operation for forming images. The three-dimensional display device comprising: a convex lens array 2 where a plurality of convex lenses 2a are arranged, an image display 3 arranged on or near a focal plane of the lens array 2, an operating means to calculate the farthest point Pi from the image display 3 among points intersecting the object image to be displayed, on a line L starting from a pixel on the image display 3 passing through the center of the curvature of the convex surface of a plurality of said respective convex lens and heading toward the object image to be displayed in the predetermined three-dimensional space via center Cj of the curvature of the convex surface of a plurality of respective convex lens 2a, and an image controlling means for instructing to display corresponding pixels Cij on the image display 3 based on the image information Pi calculated by the operating means. A light shielding plate 12 where a plurality of pin holes are arranged, can be employed in place of the lens array 2.

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PATENT SPECIFICATION

THREE-DIMENSIONAL IMAGE DISPLAY DEVICE

Field of the Invention

The present invention relates to a three-dimensional image display device particularly applicable to the following fields.

① Medicine:

Diagnosis through images, Operation aid, Remote diagnosis, Informed consent etc.

② Advertisement:

Bill board, Product sample/display, Demonstration etc.

③ Art:

Art object, Painting, Graphic art, the Interior, Exhibition in art galleries/museums etc.

④ Entertainment:

Movie, Game, various Playing machines, Exhibition at attractions/theme pavilions and the like, Training and exercise in sports etc.

⑤ Information/Multi-media:

TV broadcast, TV conference, TV phone, Virtual reality, the Internet etc.

⑥ Simulation:

Driving exercise and operation planning for cars, airplanes, ships and space ships etc.

⑦ Design Aid:

Modeling, Strength test, Destruction test etc.

⑧ Educational aid:

Specimen of human bodies, Biological objects and DNA

structures, Celestial bodies, Map etc.

⑨ Miscellaneous:

Book, Model, Toy, Souvenir etc.

Background of the Invention

Numerous display devices for displaying motion or still pictures in a space have been developed, but most of them show different pictures viewed from the right and left eyes so as to add stereo feeling to these pictures. In these devices, one image is not displayed in the space but taking a parallax into consideration, two different images viewed from right and left eyes are displayed in these devices so that observers can recognize these right and left eye views as one image, which merely gives observers stereo feelings.

Since the parallax is determined by a distance between right and left eyes, it is naturally different from each observer. Therefore when two different two-dimensional images are recognized as one three-dimensional image, but it is recognized differently by respective observers.

In the above-mentioned method where two different two-dimensional images are recognized as one three-dimensional image, observers merely observe the same one three-dimensional image from a different angle, but do not observe a different corresponding three-dimensional image from that angle.

In addition, since in the above-mentioned method different two-dimensional image having an artificial parallax viewed with right and left eyes are forcibly recognized as the three-dimensional image, there is a problem that observers are exhausted when observers try to recognize the three-dimensional image.

As a three-dimensional displaying method, which enables observers to recognize an image as a stereo image regardless of parallaxes, positions, observing directions, observing with one eye or two eyes of observers without

using any special spectacles, enables to be used in circumstances where display devices are difficult in use and enables to be observed by other people simultaneously with one display device, integral photographic systems have been known.

As shown in FIG.6 this method employs an image display means 3 arranged on the side of a surface 2b formed by center points of curvatures of convex surfaces of a convex lens array 2 where a plurality of convex lenses 2a are arranged, and employs an image forming means (not shown in the figure) to form images on the image display device. A liquid crystal display device, a Brown tube display device, a plasma display device, liquid crystal projector or a film projector with screen, or a printed image or developed film image etc. may be used as the image display means 3.

The convex lens array 2 comprises a plurality of convex lenses 2a and since it resembles a compound eye of an insect, it is called a fly eye lens plate or a compound eye lens. These convex lenses 2a may be arranged in a lattice configuration as shown in FIG.7A or arranged in a hexagonal configuration as shown in FIG.7B.

Object images shot by cameras and the like or computer generated two- or three-dimensional characters or graphics etc. can be used as objects to be displayed.

In order to form an image on the image display means 3 by calculation with the aid of an image forming means (not shown in drawings), a point on the image display means 3 formed by a projected light irradiated from a randomly selected point on an object image to be displayed in a predetermined three-dimensional space and passing through a center point Cj of the curvature of the convex surface of the convex lens 2a, is calculated as shown in FIG.8. A projected image on the image display means is formed by repeating these calculations on all points on the object image to be displayed passing through center points Cj of the curvatures of convex lenses 2a.

The projected image on the image display means 3, originated from the object image 4 to be displayed, which pass through the center points Cj of curvatures of convex lenses 2a, is displayed for example on a liquid crystal display device and the projected image heads for a predetermined three-dimensional space when the image display means 3 is irradiated by a back light 6 from the right side as shown in FIG.9. A plurality of rays R corresponding to respective points to be projected in the three-dimensional space are converged one point to form a new light source O which an observer W can observe as a three-dimensional image.

As shown in FIG.10, in place of the lens array, three-dimensional image display device 11 may comprise a light shielding plate 12 where a plurality of pin holes 12a, an image displaying means 13 arranged a predetermined distance from the light shielding plate 12 and an image forming means (not shown in FIG.10) for forming images on the image displaying means 13.

A plurality of pin holes 12a are perforated on the light shielding plate 12, where pin holes 12a may be arranged either in a lattice configuration as shown in FIG.11A or in a honey comb configuration as shown in FIG.11B.

The image can be also displayed in the predetermined three-dimensional space by utilizing the light shielding plate 12 in the same way as the above-mentioned convex lens array 2, by adjusting pin holes 12a at positions corresponding to curvature centers Cj of the convex surfaces of convex lens 2a.

As a conventional art regarding the above-mentioned integral photography, the Japanese laid open patent No. 4-133049 discloses a method to record three-dimensional still images, where the convex lens array is used for displaying three-dimensional images and an XYZ plotter and recording media for recording three-dimensional still pictures on the recording media by moving a point light source mechanically, are disclosed.

The Japanese laid open patent No. 10-186275 where the above-mentioned integral photography is employed, discloses a three-dimensional

display device capable of being manufactured easily, without having distinct respective lens marks, having excellent focusing performance and displaying three-dimensional images in a state keeping enough brightness. The three-dimensional display device has a feature that gaps among a plurality lens elements comprising a lens array, are shielded by light shielding members.

In these conventional three-dimensional display devices, images to be displayed on the image display means 3 are formed through calculations executed by the image forming means in a way shown in FIG.8. However, since the amount to be calculated correspond to a product of the number of points comprising the object image to be displayed in the predetermined three-dimensional space and the number of lenses on the lens array (or the number of pin holes on the light shielding plate) and, since an additional hidden surface process (a process to remove actually unobserved points) is necessary, a huge amount of calculation is required. Since moving pictures requires forming a lot of images at a high rate, a large scaled three-dimensional display device is required, consequently it requires a higher cost.

Disclosure of the Invention

The present invention is carried out in view of the above-mentioned conventional problems so as to provide a three-dimensional display device capable of forming images at a high rate by remarkably reducing the amount of calculation.

Other objective of the present invention is to provide a three-dimensional display device with a large display screen and a three-dimensional display device capable of displaying more vivid images.

In order to attain the above-mentioned objectives, the three-dimensional display device according to the present invention comprises: the convex lens array where a plurality of convex lenses are arranged, the image display means arranged on or near a focal plane of the lens array; an operating means

to calculate the farthest point from the image display means among points intersecting the object image to be displayed, on a line starting from each pixel on the image display means, passing through the center of the curvature of the convex surface of a plurality of respective convex lenses and heading toward the object image to be displayed in the predetermined three-dimensional space; and an image controlling means for instructing to display corresponding pixels on the image display means based on the image information calculated the operating means.

The three-dimensional display device according to the present invention comprises: the light shielding plate where a plurality of pin holes are arranged; the image display means arranged at the predetermined distance from the light shielding plate; the operating means to calculate the farthest point from the image display means among points intersecting the object image to be displayed, on a line starting from the pixel on the image display means, passing through a plurality of respective pin holes and heading toward the object image to be displayed in the predetermined three-dimensional space; and the image controlling means for instructing to display corresponding pixels on the image display means based on the image information calculated the operating means.

Since the amount to be calculated by the operating means is, for example, a product of pixels on the image display means and a resolution along a vertical direction of the object image to be displayed in the predetermined three-dimensional space, the amount to be calculated according to the present invention is capable of reducing to a large extent by employing the above-mentioned three-dimensional image display device. And since additional hidden surface process is simultaneously executed according to the present method, the amount to be calculated is further reduced so that images can be formed at a high rate.

When the convex lens array and the light shielding plate where pin holes

are arranged, are compared, the latter is easier to manufacture, but the convex lens array is capable of accumulating light so that more bright images are obtained.

A three-dimensional display device having a constitution of a plurality of image display means and a plurality of the above-mentioned lenses or a constitution of a plurality of image display means and a plurality of the above-mentioned pin holes, namely, one image display means is arranged for a plurality of respective convex lenses or pin holes, can be arranged. In addition a plurality of the above-mentioned image display means can be arranged for one above-mentioned lens array or one light shielding plate.

Since a plurality of the image display means can be arranged in the three-dimensional image display device, a image display screen having any dimension can be attained so that a three-dimensional image display device having a large scaled screen can be provided.

A diffusing plate can be arranged between a point determined by lines irradiated from respective pixels of the image display means and passing through respective center points of the curvatures of the convex surfaces of a plurality of the convex lenses or respective pin holes intersect each other and a point where the observer's eyes are positioned.

By introducing the diffusing plate even when observer's eyes are not positioned on the lines irradiated from respective pixels of the image display means and passed through respective center points of the curvatures of the convex surfaces of a plurality of the convex lenses or respective pin holes, other points on the image display means not on the above mentioned lines are also observed so that a resolution of the projected image in the predetermined three-dimensional space is enhanced because an apparent size of pixels become smaller than a diameter of the convex lens or the pin hole.

Moving pictures can be displayed in the predetermined three-dimensional space by successively calculating with the operating means and

successively instructing from the controlling means.

According to the present invention, since images can be formed at the high rate as mentioned above, more vivid images can be displayed even when the moving picture is displayed. An apparent resolution of the moving picture can be improved, since an afterimage effect of observers' eyes can be utilized.

Brief Description of Drawings

FIG.1 is a schematic diagram for explaining a calculating method by the operating means in a first embodiment of the three-dimensional display device according to the present invention.

FIG.2 is a schematic diagram for explaining the calculating method by the operating means in the first embodiment of the three-dimensional display device according to the present invention.

FIG.3 is a schematic diagram showing a second embodiment of the three-dimensional display device according to the present invention, where one convex lens is arranged to one image display means.

FIG.4 is a schematic diagram showing a third embodiment of the three-dimensional display device according to the present invention, where one pin hole is arranged to one image display means.

FIGs.5A and 5B are a schematic diagram showing a fourth embodiment of the three-dimensional display device according to the present invention, where FIG.5A shows the three-dimensional display device without the diffusing plate and FIG.5B shows the three-dimensional display device equipped with the diffusing plate.

FIG.6 is a schematic diagram showing a conventional embodiment of the three-dimensional display device employing the convex lens array where a plurality of convex lenses are arranged.

FIGs.7A and 7B are schematic diagrams showing configurations of convex lenses in the three-dimensional display device in FIG.6, where FIG.7A

shows a lattice configuration and FIG.7B shows a honey comb configuration.

FIG.8 is a schematic diagram for explaining a forming method of object images to be displayed in the three-dimensional space in the conventional three-dimensional display device, projected on the image display means via convex lens array, by calculation.

FIG.9 is a schematic diagram for explaining a displaying method in the three-dimensional space by employing the conventional three-dimensional display device.

FIG.10 is a schematic diagram showing another conventional example of the three-dimensional display device employing the light shielding plate where a plurality of pin holes are arranged.

FIGs.11A and 11B are schematic diagrams showing configurations of convex lenses in the three-dimensional display device in FIG.10, where FIG.11A shows a lattice configuration and FIG.11B shows a honey comb configuration.

Detailed Description of Preferred Embodiments

Hereinafter embodied examples of the three-dimensional display devices according to the present invention are described by referring drawings.

As a first embodied example, a three-dimensional display device shown in FIG.6 comprising the lens array 2 where a plurality of convex lenses 2a are arranged and the image display means 3 arranged at the side of the surface 2b determined by center points of curvatures of convex surfaces of convex lenses 2a of the convex lens array 2 is explained.

In the same way as the conventional display devices, the liquid crystal display device, the Brown tube image display device, the plasma display device, the liquid crystal or film projector with the screen, or the printed or developed film image etc. can be employed as the three-dimensional display device 3. Two-dimensional or three-dimensional character or graphic images

formed by photographs of real objects and computer graphics can be used as objects to be displayed.

In addition to the above-mentioned convex lens array 2 and image display means 3, the operating means and the image controlling means, both are not shown in the figure, are equipped in the three-dimensional display device according to the present invention.

As shown in FIG.1, the operating means calculates a farthest point Pi from the three-dimensional display means 3 among points in an object image 4 to be displayed, on an intersecting straight line L starting from respective pixel Dij on the image display means 3, passing through respective center points Cj of the curvatures of respective convex surfaces of a plurality of convex lenses 2a and directing toward the object image 4 to be displayed. The image controlling means instructs to display image information of the point Pi calculated by the operating means, onto the corresponding pixel Dij of the image display means 3.

A whole image to be displayed on the image display means 3 is formed by executing the above-mentioned procedure over the whole pixels on the image display means 3.

FIG.2 is a schematic diagram showing a calculating method for selecting the farthest point Pi from the three-dimensional display means 3 among points in the object image 4 to be displayed, on the intersecting straight line L starting from respective pixel Dij on the image display means 3, passing through respective center points Cj of the curvatures of respective convex surfaces of a plurality of convex lenses 2a and directing toward the object image 4 to be displayed.

The image display means 3 is arranged below the convex lens array 2, where a distance between them is defined as "h" and a center point of the curvature of the convex surface of the convex lens 2a is defined as "Cj". It is assumed that the image to be displayed (corresponds to 4 in FIG.1) in the

predetermined three-dimensional space is located above the convex lens array.

Here Pi is defined as the farthest point among points in the object image 4 to be displayed, on the intersecting straight line L starting from a pixel Dij on the image display means 3, passing through a center point Cj of a curvature of a convex surface of a convex lens 2a and directing toward the object image 4 to be displayed.

A toe of a perpendicular line to the surface 2b determined by center points of curvatures of convex surfaces of convex lenses 2a is defined as "Qj". And a toe of a perpendicular line from the center point Cj of the curvature of the convex surface of the convex lens 2a, to the image display means 3 is defined as "Cj'". Since a triangle CjCj'Dij and a triangle PiQjCj are similar figures, the following equation is derived:

$$CjQj : PiQj = DijCj' : h$$

Since DijCj' is determined by a geometrical relation between the lens array 2 and the image display means 3, when either CjQj or PiQj is measured, remaining either of them can be calculated.

When the object image 4 to be displayed is scanned by stepwise vertical planes from left side in FIG.1, Pi is determined by the relation between intersecting point in the object to be displayed formed by vertical planes and the above-mentioned straight line L. Thus, PiQj is derived from the determined Pi. Consequently, CjQj in FIG.2 can be calculated based on the above-mentioned equation from obtained PiQj.

When the above-mentioned operation is executed, the amount of operation by the operating means is a product of pixels on the image display means 3 and a resolution along a depth direction of the object image to be displayed in the three-dimensional space and the amount of the calculation is remarkably reduced compared with conventional ways because only actually observed points are calculated and hidden surface process is also executed simultaneously.

One example of apparatus to carry out the above-mentioned method, namely, an actual constitution of the operating means and the image controlling means, is a combination of CT (Computerized tomography) which takes three-dimensional tomographic images, and a personal computer which execute above-mentioned operation so as to obtain image data to be displayed on the three-dimensional image display means 3. When the convex lens array is placed in front of the liquid crystal display device used as the image display means 3 on which the obtained image data are displayed, the above-mentioned three-dimensional tomographic image is displayed in the predetermined three-dimensional space situated in front of the convex lens array.

In the same way as the conventional methods in place of the convex lens array, the light shielding plate 12 where a plurality of pin holes 12a are arranged as shown in FIG.10 can be used together with the above-mentioned operational means and the image controlling means so that the three-dimensional display device according to the present invention is constituted. Since effects of the pin holes 12a in place of the convex lens array 12 are the same as in the conventional methods, further explanation is omitted.

Hereinafter the second embodiment of the three-dimensional display device according to the present invention is explained by referring FIG.3.

In the above mentioned first embodiment one image display device is used for one convex lens array 2 where a plurality of convex lenses are arranged, but individual image display devices 3 (3A to 3D) are arranged respectively to a plurality of convex lenses 2a in this embodiment so that the three-dimensional display device 1 comprises a plurality of image display means 3 (3A to 3D) and a plurality of convex lenses 2a. When this arrangement is employed, an image display surface having desired size can be constituted and the three-dimensional image display device 3 having a large display screen can be provided.

As the third embodiment of the three-dimensional display device shown in FIG.4 according to the present invention, individual image display devices 13 (13A to 13D) are arranged respectively to a plurality of pin holes 12a so that the three-dimensional display device 11 comprises a plurality of image display means 13 (13A to 13D) and a plurality of convex lenses 12a, which attains the same effect as the second embodiment.

By arranging a plurality of image display means 3 (or 13) for at least one convex lens array 2 or light shielding plate 12 in stead of one to one arrangement of the convex lens 2 or the pin hole 12a for the image display means 3 (or 13) as described in the embodiments 2 and 3, an image display surface having desired size can be constituted and the three-dimensional image display device 3 having the large display screen can be provided.

As shown in FIG.5B, a diffusing plate 5 such as a ground glass plate and the like is placed between a point O, where straight lines from respective pixels on the image display means 3 toward the object image to be displayed in the predetermined three-dimensional space via respective center points Cj of curvatures of convex surfaces of convex lenses 2a arranged on the lens array 2 intersect each other, and a position where observer W's eyes are located.

As shown in FIG.5A when the diffusing plate 5 is not placed, the observer W observes only points on the lines connected between observer W's eyes and respective center points Cj of curvatures of convex surfaces of convex lenses 2a so that only one pixel is observed for one convex lens 2a, consequently, an apparent pixel size corresponds to the diameter of the convex lens 2a.

On the other hand when the diffusing plate 5 is placed as shown in FIG.5B, the apparent pixel size looks smaller than the diameter of the convex lens 2a, which increase a resolution of a projector, because the observer W can observe other points not on the lines connected between observer W's eyes and respective center points Cj of curvatures of convex surfaces of convex lenses

2a, due to diffused lights which reach into observer W's eyes as synthesized lights S.

Although not shown in drawings, the above mentioned diffusing plate 5 can be used in the case of the light shielding plate 12 in place of the convex lens array 2. In this case, the apparent pixel size looks smaller than a pin hole spacing, which increase a resolution projected in the predetermined three-dimensional space, because through the diffusing plate 5 the observer W can observe other points not on lines from respective pixels on the image display means toward object image to be displayed in the predetermined three-dimensional space via a plurality of pin holes even when observer W's eyes are not on these lines.

Moving pictures can be displayed in the predetermined three-dimensional space when the calculation by the above-mentioned operating means and instructions by the image controlling means are successively executed. Since the residual image effects in the human eyes are attained by moving pictures, the apparent resolution can be improved.

As explained above, images can be formed at higher rate, since the amount of operation for forming images is remarkably reduced by the present invention compared with conventional methods. Due to reduced operating amount, a smaller scaled three-dimensional display device can be provided, as a result, a less expensive three-dimensional display device can be provided.

In addition to the above-mentioned effects the present invention is capable of constituting an image display screen having any desired size and providing the three-dimensional display device having a large scaled display screen.

Further, the apparent pixel size can be reduced to less than the diameter of the convex lens or the pin hole spacing, consequently the three-dimensional display device capable of attaining higher resolutions in images projected in the predetermined three-dimensional space can be provided.

The three-dimensional image display device capable of displaying more vivid moving pictures can be provided when the calculation by the operating means and instructions by the image controlling means are successively executed, because images can be formed at high rate even when moving pictures are displayed in the predetermined three-dimensional space.

The three-dimensional image display device according to the present invention can be applied to the following fields, can provide more vivid images and can provide less expensive systems.

① Medicine:

Diagnosis through images, Operation aid, Remote diagnosis, Informed consent etc.

② Advertisement:

Bill board, Product sample/display, Demonstration etc.

③ Art:

Art object, Painting, Graphic art, the Interior, Exhibition in art galleries/museums etc.

④ Entertainment:

Movie, Game, various Playing machines, Exhibition at attractions/theme pavilions and the like, Training and exercise in sports etc.

⑤ Information/Multi-media:

TV broadcast, TV conference, TV phone, Virtual reality, the Internet etc.

⑥ Simulation:

Driving exercise and operation planning for cars, airplanes, ships and space ships etc.

⑦ Design Aid:

Modeling, Strength test, Destruction test etc.

⑧ Educational aid:

Specimen of human bodies, Biological objects and DNA structures, Celestial bodies, Map etc.

⑨ Miscellaneous:

Book, Model, Toy, Souvenir etc.

What is claimed is:

1. A three-dimensional display device comprising:

a convex lens array where a plurality of convex lenses are arranged,

an image display means arranged on or near a focal plane of said convex lens array,

an operating means to calculate the farthest point from said image display means among points intersecting an object image to be displayed, on a straight line starting from a pixel on said image display means passing through the center of the curvature of the convex surface of a plurality of said respective convex lens heading toward said object image to be displayed in the predetermined three-dimensional space, and

an image controlling means for instructing to display corresponding pixels on said image display means based on the image information calculated by said operating means.

2. A three-dimensional display device comprising:

a light shielding plate where a plurality of pin holes are arranged,

an image display means arranged at a predetermined distance from the light shielding plate,

an operating means to calculate the farthest point from said image display means among points intersecting an object image to be displayed, on a straight line starting from a pixel on said image display means, passing through a plurality of said respective pin holes and heading toward said object image to be displayed in the predetermined three-dimensional space, and

an image controlling means for instructing to display corresponding pixels on said image display means based on the image information calculated by said operating means.

3. The three-dimensional display device according to claim 1 or claim 2, wherein;

a plurality of said image display means are respectively arranged for a plurality of said lenses or for a plurality of said pin holes, and

said three-dimensional image display device comprises a plurality of said image display means and a plurality of said convex lenses or comprises a plurality of said image display means and a plurality of said pin holes.

4. The three-dimensional display device according to claim 1 or claim 2, wherein:

a plurality of said image display means are arranged for one said convex lens array or for one said light shielding plate.

5. The three-dimensional display device according to either one of the clams 1 to 4, wherein:

a diffusing plate is arranged between a point determined by lines from respective pixels of said image display means and passed through the center points of the curvatures of the convex surfaces of a plurality of said convex lenses or said pin holes intersect each other and a position where observer's eyes are located.

6. The three-dimensional image display device according to either one of the claims 1 to 5, wherein:

a moving picture is displayed in said predetermined three-dimensional space based on the successive calculation by said operating means and simultaneous successive instructions from said controlling means.

FIG.1

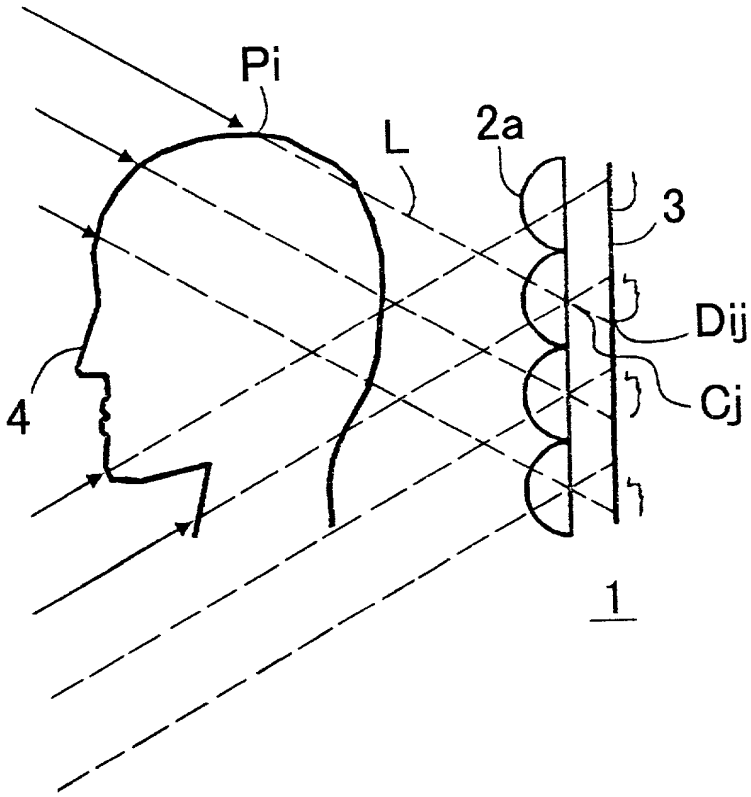


FIG.2

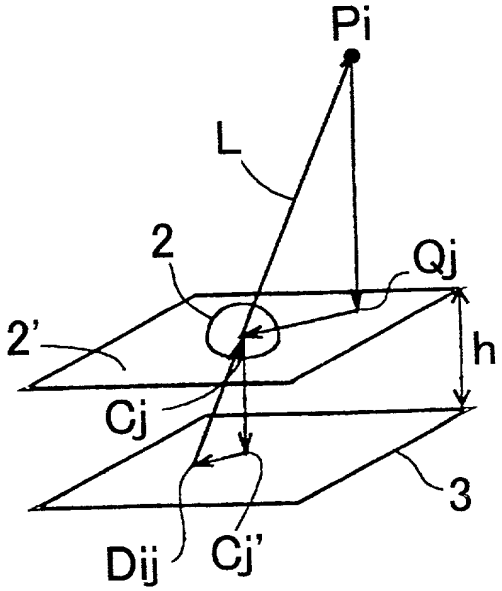


FIG.3

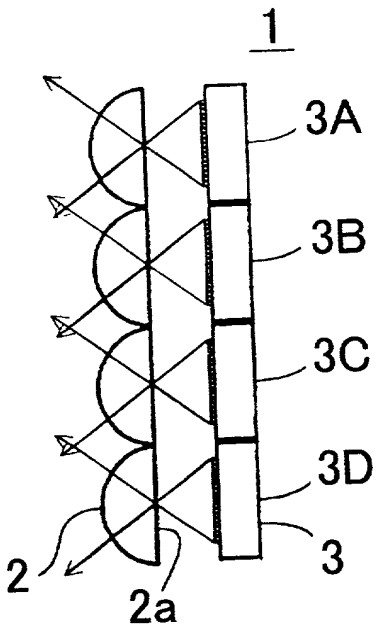


FIG.4

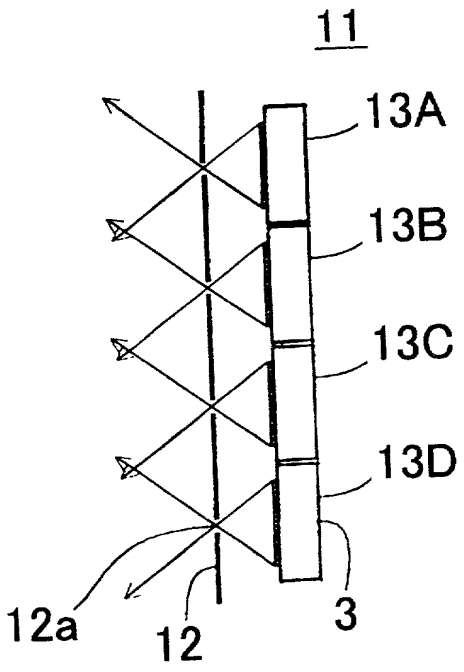


FIG.5A

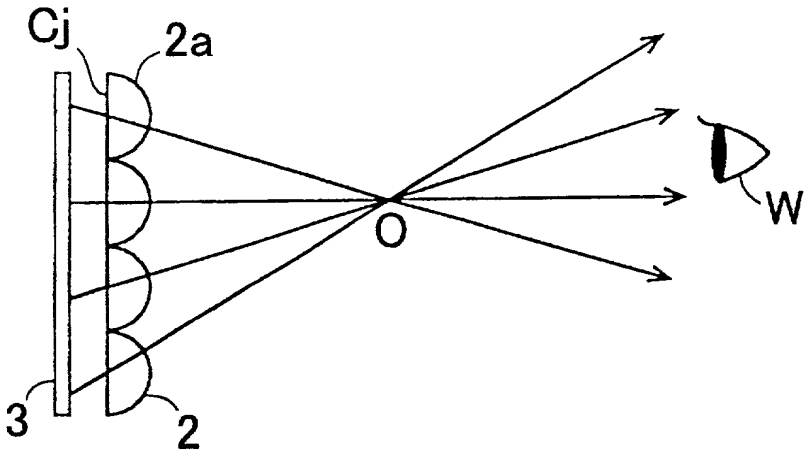


FIG.5B

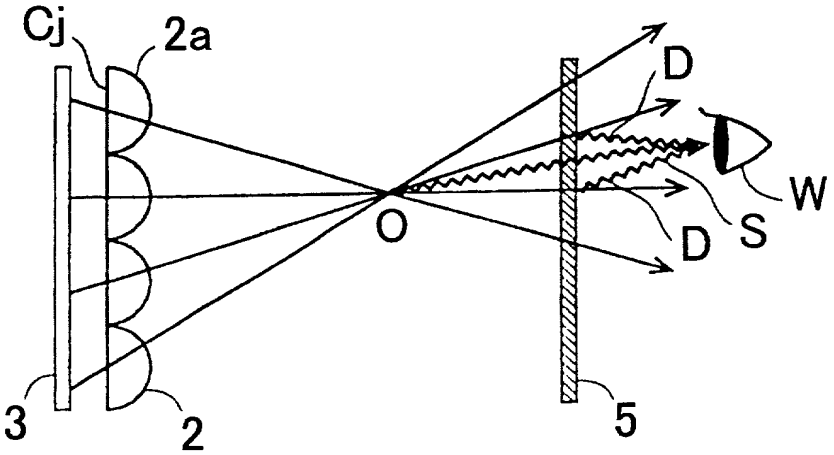


FIG.6

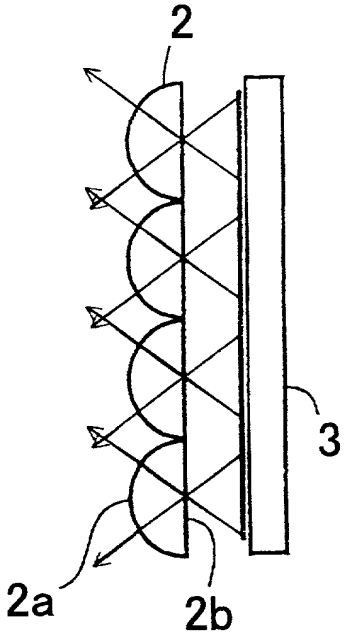


FIG.7A

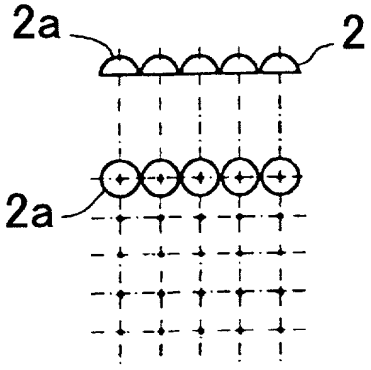


FIG.7B

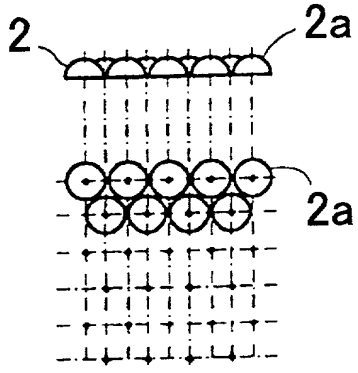


FIG.8

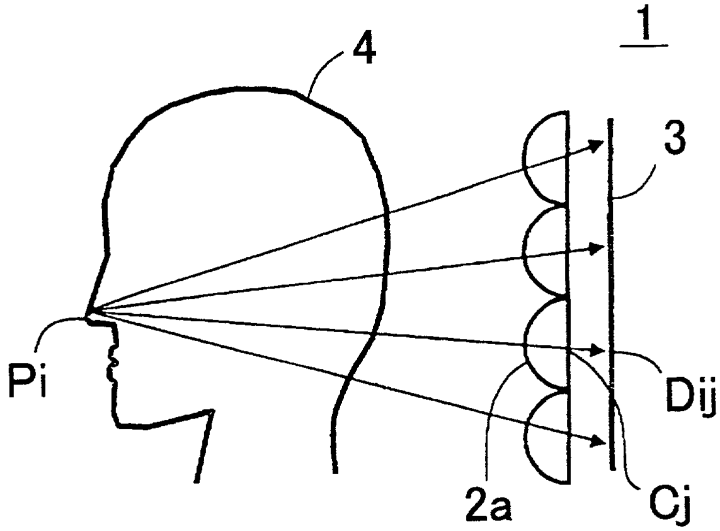


FIG.9

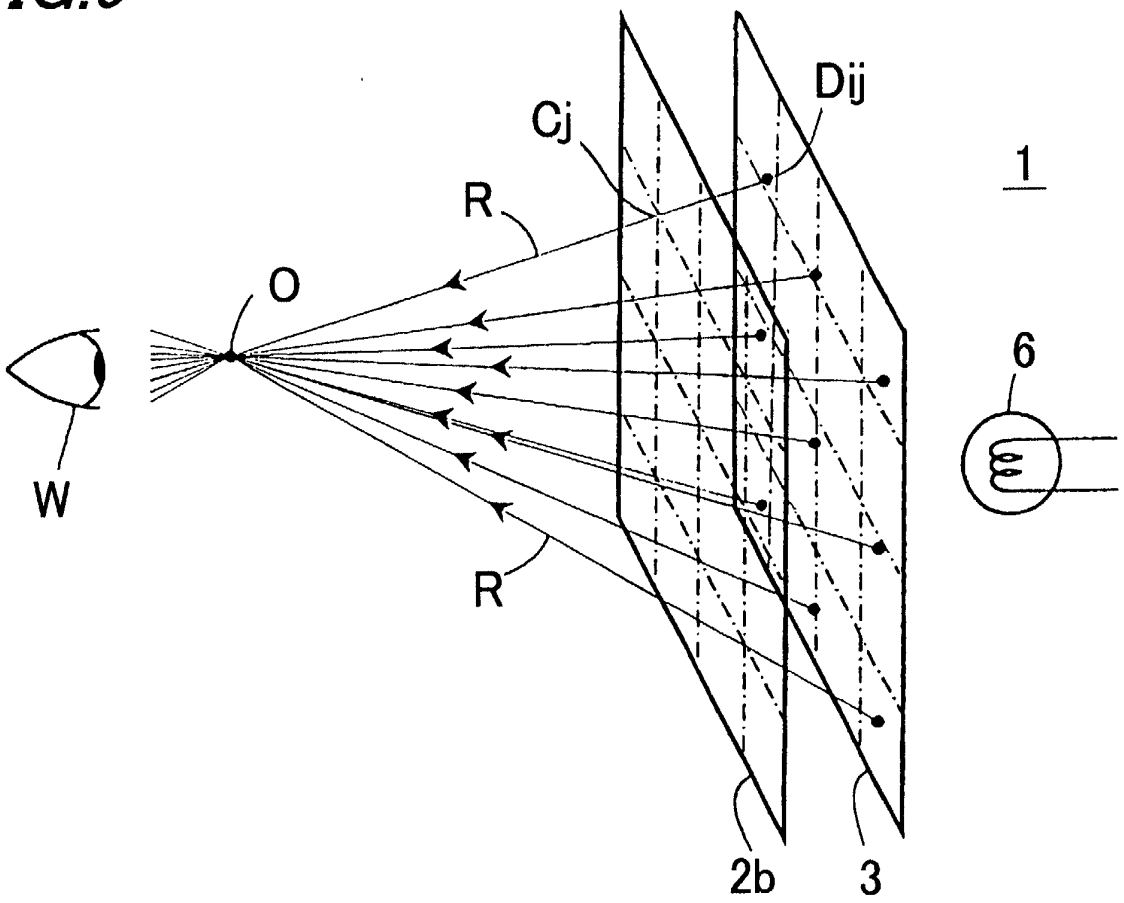


FIG. 10

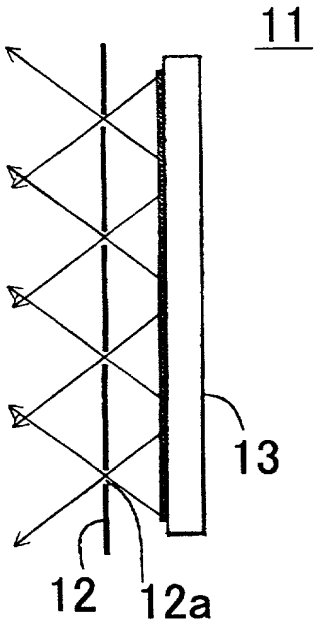


FIG. 11A

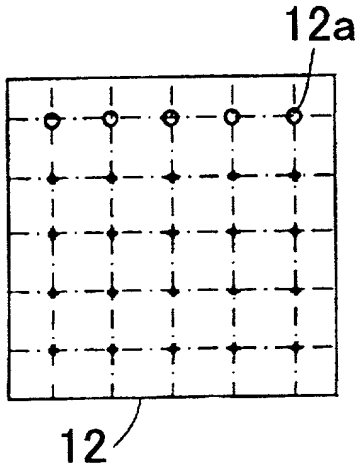
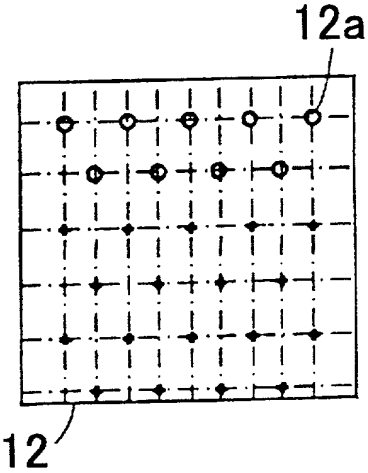


FIG. 11B



Declaration and Power of Attorney For Patent Application

特許出願宣言書

Japanese Language Declaration

私は、下欄に氏名を記載した発明者として、以下のとおり宣言する：

私の住所、郵便の宛先および国籍は、下欄に氏名に続いて記載したとおりであり、

名称の発明に関し、請求の範囲に記載した特許を求める主題の本来の、最初にして唯一の発明者である（一人の氏名のみが下欄に記載されている場合）か、もしくは本来の、最初にして共同の発明者である（複数の氏名が下欄に記載されている場合）と信じ、

_____

_____

_____

その明細書を
（該当する方に印を付す）

☐ ここに添付する。

☐ _____ 日に出願番号

第 _____ 号として提出し、

_____ 日に補正した。
（該当する場合）

私は、前記のとおり補正した請求の範囲を含む前記明細書の内容を検討し、理解したことを陳述する。

私は、連邦規則法典第37部第１章第56条（ａ）項に従い、本願の審査に所要の情報を開示すべき義務を有することを認める。

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

THREE-DIMENSIONAL IMAGE DISPLAY

DEVICE

_____,

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as

Application Serial No. _____

and was amended on _____.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Japanese Language Declaration

私は、合衆国法典第35部第119 条にもとづく下記の外国特許出願または発明者証出願の外国優先権利益を主張し、さらに優先権の主張に係わる基礎出願の出願日前の出願日を有する外国特許出願または発明者証出願を以下に明記する：

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior foreign applications
先の外国出願

(Number) (番 号)	(Country) (国 名)	(Day/Month/Year Filed) (出願の年月日)	Priority claimed 優先権の主張 Yes あり	No なし
PCT/JP99/05669	Japan	14/October/1999	☒	☐
11-84196	Japan	26/March/1999	☒	☐
			☐	☐

私は、合衆国法典第35部第120 条にもとづく下記の合衆国特許出願の利益を主張し、本願の請求の範囲各項に記載の主題が合衆国法典第35部第112 条第１項に規定の態様で先の合衆国出願に開示されていない限度において、先の出願の出願日と本願の国内出願日またはＰＣＴ国際出願日の間に公表された連邦規則法典第37部第１章第56条（ａ）項に記載の所要の情報を開示すべき義務を有することを認める：

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.) (出願番号)	(Filing Date) (出願日)	(現 況) (特許済み、係属中、放棄済み)	(Status) (patented, pending, abandoned)
(Application Serial No.) (出願番号)	(Filing Date) (出願日)	(現 況) (特許済み、係属中、放棄済み)	(Status) (patented, pending, abandoned)

私は、ここに自己の知識にもとづいて行った陳述がすべて真実であり、自己の有する情報および信ずるところに従って行った陳述が真実であると信じ、さらに故意に虚偽の陳述等を行った場合、合衆国法典第18部第1001条により、罰金もしくは禁錮に処せられるか、またはこれらの刑が併科され、またかかる故意による虚偽の陳述が本願ないし本願に対して付与される特許の有効性を損うことがあることを認識して、以上の陳述を行ったことを宣言する。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Japanese Language Declaration

委任状：私は、下記発明者として、以下の代理人をここに選任し、本願の手続を遂行すること並びにこれに関する一切の行為を特許商標庁に対して行うことを委任する。
（代理人氏名および登録番号を明記のこと）

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (*list name and registration number*)

John G. Gilfillan, III (Reg. No. 22,746)
Elliot M. Olstein (Reg. No. 24,025)
Raymond J. Lillie (Reg. No. 31,778)
Glennon G. Troublefield (Reg. No. 39,050)
William Squire (Reg. No. 25,378)
John N. Bain (Reg. No. 18,651)
Alan J. Grant (Reg. No. 33,389)
Francis C. Hand (Reg. No. 22,280)

書類の送付先：

Send Correspondence to:
William Squire, Esq.
Carella, Byrne, Bain, Gilfillan, Cecchi, Stewart & Olstein
6 Becker Farm Road,
Roseland, New Jersey 07068-1739

直通電話連絡先：（名称および電話番号）

Direct Telephone Calls to: (*name and telephone number*)
William Squire, Esq. at
Telephone No. (973)994-1700

唯一のまたは第一の発明者の氏名	Full name of sole or first inventor **Takeyoshi DOHI**
同発明者の署名　日付	Inventor's signature　Date Takeyoshi Dohi　August 15, 2001
住所	Residence **2-6-30, Nakamachi, Setagaya-ku, Tokyo 158-0091 Japan**
国籍	Citizenship **Japan**
郵便の宛先	Post Office Address **2-6-30, Nakamachi, Setagaya-ku, Tokyo 158-0091 Japan**
第２の共同発明者の氏名（該当する場合）	Full name of second joint inventor, if any **Susumu NAKAJIMA**
同第２発明者の署名　日付	Second Inventor's signature　Date Susumu Nakajima　August 17, 2001
住所	Residence **1-1-B1117, Ogura, Saiwai-ku, Kawasaki-shi, Kanagawa 211-0954 Japan**
国籍	Citizenship **Japan**
郵便の宛先	Post Office Address **1-1-B1117, Ogura, Saiwai-ku, Kawasaki-shi, Kanagawa 211-0954 Japan**

（第六またはそれ以降の共同発明者に対しても同様な情報および署名を提供すること。）

(Supply similar information and signature for third and subsequent joint inventors.)

Japanese Language Declaration

	Full name of third joint inventor, if any Ichiro SAKUMA
日付	Third Inventor's signature Date Ichiro Sakuma Aug. 16. 2001
住所	Residence 719-24, Kawashimacho, Hodogaya-ku, Yokohama-shi, Kanagawa 240-0045 Japan
国籍	Citizenship Japan
郵便の宛先	Post Office Address 719-24, Kawashimacho, Hodogaya-ku, Yokohama-shi, Kanagawa 240-0045 Japan

	Full name of fourth joint inventor, if any Ken MASAMUNE
日付	Fourth Inventor's signature Date Ken Masamune Aug. 21, 2001
住所	Residence 2-17-1, Minamisenzoku, Ota-ku, Tokyo 145-0063 Japan
国籍	Citizenship Japan
郵便の宛先	Post Office Address 2-17-1, Minamisenzoku, Ota-ku, Tokyo 145-0063 Japan

	Full name of fifth joint inventor, if any Hiroshi Iseki Hiroshi ISEKI
日付	Fifth Inventor's signature Date Hiroshi Iseki Aug. 17 2001
住所	Residence Suwavanperu 1F 3-7-33 Nishinippori, Arakawa-ku, Tokyo 116-0013 Japan
国籍	Citizenship Japan
郵便の宛先	Post Office Address Suwavanperu 1F 3-7-33 Nishinippori, Arakawa-ku, Tokyo 116-0013 Japan

	Sixth Inventor's signature Date Etsuko KOBAYASHI
日付	Full name of sixth joint inventor, if any Etsuko Kobayashi Aug. 16. 2001
住所	Residence 1-21-3, Mitsuidai, Hachioji-shi, Tokyo 192-0014 Japan
国籍	Citizenship Japan
郵便の宛先	Post Office Address 1-21-3, Mitsuidai, Hachioji-shi, Tokyo 192-0014 Japan

（第六またはそれ以降の共同発明者に対しても同様な情報および署名を提供すること。）

(Supply similar information and signature for third and subsequent joint inventors.)

Japanese Language Declaration

	Full name of seventh joint inventor, if any **Sumihisa ORITA**
日付	Seventh ~~Inventor's~~ signature Sumihisa Orita Date August 16, 2001
住所	Residence **1554-8, Nakabyo, Abike-shi, Chiba 270-1121 Japan**
国籍	Citizenship **Japan**
郵便の宛先	Post Office Address **1554-8, Nakabyo, Abiko-shi, Chiba 270-1121 Japan**

日付	Date
住所	Residence
国籍	Citizenship
郵便の宛先	Post Office Address

日付	Date
住所	Residence
国籍	Citizenship
郵便の宛先	Post Office Address

	Date
日付	
住所	Residence
国籍	Citizenship
郵便の宛先	Post Office Address